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UTILITY PATENT APPLICATION TRANSMITTAL

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APPLICATION ELEMENTS
See MPEP chapter 600 concerning utility patent application contents.

1. X Fee Transmittal Form
(Submit an original, and a duplicate for fee processing)

2. X Specification (Total Pages 44)
(preferred arrangement set forth below)
- Descriptive Title of the Invention
- Cross References to Related Applications
- Statement Regarding Fed sponsored R & D
- Reference to Microfiche Appendix
- Background of the Invention
- Brief Summary of the Invention
- Brief Description of the Drawings (if filed)
- Detailed Description
- Claims
- Abstract of the Disclosure

3. X Drawings(s) (35 USC 113) (Total Sheets 13)

4. X Oath or Declaration (Total Pages 6)
   a. ___ Newly Executed (Original or Copy)
   b. ___ Copy from a Prior Application (37 CFR 1.63(d))
   (for Continuation/Divisional with Box 17 completed) **(Note Box 5 below)**
   i. ___ DELETIONS OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).

5. ____ Incorporation By Reference (useable if Box 4b is checked)
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

6. ____ Microfiche Computer Program (Appendix)

7. ______ Nucleotide and/or Amino Acid Sequence Submission
(if applicable, all necessary)
a. ____ Computer Readable Copy
b. ____ Paper Copy (identical to computer copy)
c. ____ Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. ______ Assignment Papers (cover sheet & documents(s))
9. ______ a. 37 CFR 3.73(b) Statement (where there is an assignee)
______ b. Power of Attorney
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11. ______ a. Information Disclosure Statement (IDS)/PTO-1449
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UNITED STATES PATENT APPLICATION

FOR

METHOD AND APPARATUS FOR ERROR DATA RECOVERY

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METHOD AND APPARATUS FOR ERROR DATA RECOVERY

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to the recovery of lost or damaged encoded data. More particularly, the present invention relates to the minimizing of quality degradation caused by error propagation in bitstreams containing lost or damaged encoded data.

2. ART BACKGROUND

It is quite common to compress data to minimize transmission or storage bandwidth requirements. One type of compression process is referred to as variable length coding. In variable length coding processes, the signal is typically divided into several localized regions, also referred to as blocks, and is coded by quantizing each region according to its signal activity level. In an exemplary signal such as signals representative of digital images, different parts of the images have different activity levels and are therefore coded with a different number of quantization bits.

The information regarding the number of quantization bits used for coding different regions is used by the decoder to delineate the respective quantization bits of each block from the received bitstream, which in turn is used to decode the blocks. Therefore, when the information regarding the number of quantization bits used to encode data is lost, a recovery process is implemented to estimate the number of quantization bits used to generate the codes representative of the data. If the number of quantization bits is not accurately estimated, the error incurred will propagate through the bitstream as

the decoder is unable to determine the location of the end of one block, and therefore the beginning of the next block.

One type of variable length encoding is known as Adaptive Dynamic Range Coding (ADRC). For further information regarding ADRC, see, "Adaptive Dynamic Range Coding Scheme for Future HDTV Digital VTR", Kondo, Fujimori, Nakaya, Fourth International Workshop on HDTV and Beyond, September 4-6, 1991, Turin, Italy.

In one example of ADRC, blocks are encoded using a minimum pixel value (MIN), the dynamic range (DR) of pixel values in the block, the motion flag (MF) indicative of temporal activity and the quantization codes (Q codes) representative of each pixel in a block. The Q codes are generated based upon a minimum value, quantization step and the original pixel value. The quantization step is determined by the DR of the block and the number of quantization bits (Qbit), wherein the Qbit is a function of DR.

When the encoded bits are received in the decoder, the Qbit and MF information of each block is needed to delineate the portion of the bitstream corresponding to each block , and in turn to decode the block. If the DR and/or MF of the block is damaged, it is necessary to recover or estimate the information in order that the blocks can be decoded. At the same time, in case of a recovery failure, this error will likely result in incorrect decoding of the rest of the blocks and, in turn, severe picture degradation, since the starting point of subsequent blocks in the bitstream will be incorrectly identified.

SUMMARY OF THE INVENTION

The present invention provides a mechanism for preventing quality degradation of decoded data during the decoding of encoded data. In one embodiment, error propagation is detected and corresponding data is flagged. An error recovery process is then applied to the flagged data. In an alternate embodiment, candidate hypotheses are calculated for lost/damaged data. A score distribution is used for detection of the false candidate hypotheses. The data are flagged if their score distribution is within a range defined by a threshold and an error recovery process is applied to recover those data having associated error flags set.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects, features and advantages of the present invention will be apparent to one skilled in the art in light of the following description in which:

Figure 1a illustrates one embodiment of a system of the present invention, **Figure 1b** illustrates an alternate embodiment of the system of the present invention, and **Figure 1c** illustrates an alternate embodiment of the system of the present invention.

Figure 2 is a block diagram illustration of one embodiment of a sub-system for the recovery of block parameters.

Figure 3 is a block diagram illustration of one embodiment of a sub-system for determining a measure for different hypotheses.

Figure 4 is a block diagram illustration of one embodiment of a sub-system for scoring the different hypotheses.

Figure 5 illustrates an example of the effect of error propagation on score distribution.

Figure 6 shows exemplary histograms of score distribution for recovery of block parameters.

Figure 7 illustrates an example of successive score distribution following Qbit and Motion Flag recovery.

Figure 8 is a block diagram illustration of one embodiment of a sub-system for detection of error propagation.

Figure 9 is a flow diagram illustrating one embodiment of a process for recovering lost or damaged data.

Figure 10 is a flow diagram illustrating an alternate embodiment of a process for recovering lost or damaged data.

Figure 11 is a flow chart illustrating one embodiment of a pixel error recovery process.

Figure 12 illustrates parameters of an audio signal.

DETAILED DESCRIPTION

In the following description, for purposes of explanation, numerous details are set forth in order to provide a thorough understanding of the present invention. However, it will be apparent to one skilled in the art that these specific details are not required in order to practice the present invention. In other instances, well known electrical structures and circuits are shown in block diagram form in order not to obscure the present invention unnecessarily.

The system and method of the present invention provides an innovative mechanism for preventing quality degradation caused by error propagation in variable length encoded data. The discussion herein is directed to the recovery of image data, and in particular, Adaptive Dynamic Range Coding (ADRC). However, the invention is not limited to image data and can be applied to other types of correlated data including audio data. Furthermore, the present invention is not limited to ADRC; other variable length encoding processes may also be used. For example, the present invention is applicable to coding processes using Discrete Cosine Transform (DCT). In one embodiment, DCT coefficients of individual blocks can be quantized based upon respective activity levels, and the quantized coefficients are transmitted.

One embodiment of a system that operates in accordance with the teachings of the present invention is illustrated in **Figure 1a**. The encoded bitstream of data, error flags indicating portions of data that are lost or damaged (lost/damaged), and decoded data (referred to in this example as image data) are input to Qbit and Motion Flag recovery circuit 10. The Qbit and Motion Flag recovery circuit 10 generates hypotheses, referred to herein as candidate hypotheses, of possible number of quantization bits (Qbit) used and motion flag (MF) values. As will be described in more detail below, a score is generated with respect to each hypothesis and the hypothesis with the best

score, e.g., minimum score, is selected as the recovered values. The data decoded using the selected hypothesis is output as the decoded data to the memory 30.

The scores and error flags corresponding to data decoded using the selected hypothesis is input to error propagation detection circuit 20. As will be discussed below, error propagation detection circuit 20 evaluates candidate hypotheses to generate candidate hypotheses results used to detect error propagation. In one embodiment, circuit 20 examines the score distribution and detects error propagation due to false candidate decoding. Other evaluation techniques may be used, including evaluation of score distribution patterns or other metrics. Pixel error recovery block 40, receives the decoded data error flags as well as flags that may have been generated by the error propagation detection circuit 20 to indicate that pixel error recovery is warranted and performs a pixel error recovery process to recover pixel data that may not be correct due to error propagation.

An alternate embodiment is illustrated in **Figure 1b**. In this embodiment, a general purpose or specially configured processing system 50 performs the methods described herein. In this embodiment, the processing system 50 includes a processor 55, a memory 60 and input/output circuitry 65. Other circuitry not shown herein may also be included.

In one embodiment, the memory can store instructions, which when executed by processing system 50, perform the methods described herein. Alternately, the instructions may be stored on other storage media or transmitted across a transmission media, such as a network, to the processor 55. Memory 60 can also be configured to store data used and generated as described herein.

Input/output circuitry 65, receives the encoded data, error flags and image data for processing by processing system 50 and outputs the recovered data generated.

An alternate embodiment is illustrated by **Figure 1c**. In this embodiment, the bitstream of data is input into decoder 70 and candidate decoder 72. The decoder 70 decodes those portions of the bitstream that are decodable using standard available decoding processes, i.e., portions containing no errors. Candidate decoder 72 generates candidate decodings and selects a best candidate decoding as discussed herein. Error propagation detection circuit 74 detects errors which occur due to error propagation, for example, those errors caused by selection of an incorrect candidate decoding. The prevent degradation circuit 76 receives the decoded data output by decoder 70 and error propagation flags generated by error propagation detection circuit 74 and performs block processing to recover blocks of data flagged to have errors. In one embodiment, block processing estimates block data using neighboring block data. Other block processing techniques may be used.

Pixel error flag circuit 80 receives flags indicating the pixel data which may contain errors. Typically, the flags are generated using known Error Correction Code (ECC) techniques.

Pixel error recovery circuit 78 receives input from prevent degradation circuit 76 and pixel error flag circuit 80 and performs a pixel error recovery process data for having corresponding error flags set. A pixel error recovery process, such as the classified adaptive error recovery process discussed below, may be used.

A more detailed block diagram of one embodiment of the Qbit and Motion Flag recovery circuit is shown in **Figure 2**. In this embodiment, candidate decoding and error measure circuit 205 determines possible

hypotheses, i.e., values of Qbit and/or MF, and generates candidate decodings of Q codes based upon each of the hypotheses. Alternately, the hypothesis can be evaluated in the encoded domain, eliminating the need for decoding the data for all hypotheses.

An error measure is generated for each hypothesis. In one embodiment, an error measure may be determined based upon how well the candidate decoding fits into with other decoded data. For example, the measure may show how well correlated the candidate decoding is with other decoded data. Linear error, square error and Laplacian measurements may also be used.

One measure that can be used is square error measurements on decoded data. In one embodiment, the decoded domain square error measurement can be obtained using the following formula:

$$SquareError(HypNo) = \sum_{i} \sum_{j \in R(i)} \left[y_i' - y_j \right]^2$$

where y_i' represents the i-th decoded pixel value of the block being recovered for the hypothesis HypNo. and y_j represents one of the neighboring decoded pixel values of the i-th pixel, R(i) represents a set of neighboring pixels to the i-th pixel and

$$y_i' = MIN + \frac{DR(q_i + 0.5)}{2^Q}$$

where DR is the recovered dynamic range value, q_i is the i-th Q code and Q is the Qbit number corresponding to the hypothesis HypNo.

In one embodiment, the data in the encoded domain is evaluated with respect to each hypothesis to generate corresponding error measures. For

example, a linear error measure may be determined from encoded data as follows:

$$LinearError(HypNo) = \sum_i \sum_{j \in R(i)} \left| a1_i - a2_j \right|$$

$$a1_i = adj(q1_i)$$

$$adj(q1_i) = 2^{5-Q1} q1_i + 2^{4-Q1}$$

$$a2_j = adj(q2_j)$$

$$adj(q2_i) = 2^{5-Q2} q2_j + 2^{4-Q2} + Offset$$

$$Offset = \frac{1}{N} \sum_i \sum_{j \in R(i)} (q1_i - q2_j)$$

where $q1_i$ represents the Q code of the i-th pixel of the block being recovered (block 1), $q2_j$ represents the Q code of a neighboring pixel of the i-th pixel of a neighboring block (block 2), N is the number of neighboring-pair relations, Q1 and Q2 respectively represent the hypothesized Qbit number of the block being recovered and the Qbit number of the neighboring block. R(i) represents the neighboring pixels with respect to the i-th pixel of the block being recovered, and a1i and a2j represent a rescaled value of a2j. The function adj() as defined above performs a Q code rescaling process to normalize the values for more accurate measurements.

Figure 3 illustrates one embodiment of a circuit which implements the encoded domain linear error measure. Candidate decodings 305, 307, 309, 311, 313, 315 are performed based upon the different hypothesis, e.g., hypotheses 0-5. For each hypothesis, the hypothesized Q code for the block to be recovered (q1), the Q code for a neighboring block (q2) and Q code error flags determined for the particular hypothesis are input to a linear error measurement circuit 317, 319, 321, 323, 325, 327 to generate the linear error measure, Linear Error 0-5.

The measure may be determined in accordance with the equations described above.

Referring back to **Figure 2**, the error measures are input to scoring circuit 210 which determines which hypothesis generates the best score. A variety of techniques can be used to determine the best score. For example, confidence weighted scoring, majority based scoring, simple accumulation based scoring and majority decision scoring can be used. In one embodiment the score is determined as follows:

$$score(i) = \sum_j G\left(\frac{m(i,j) - \min(j)}{m(i,j) + \min(j)}\right)$$

where m(i, j) represents the j-th measurement for hypothesis i for the block or block group (e.g., 3 blocks which form a group), min(j) is the minimum of the j-th measurement among different hypotheses, and G() is an identity function or a monotonically increasing function, depending on the application. G may be selected to be a function that increases the sensitivity of the scoring such that incorrect hypotheses will be clearly distinguishable from the correct hypothesis. For example, a square or linear function may be used. Alternately, G may be a constant, including one having a value of unity.

Alternately, if an accumulation function of, for example, linear error measures, is performed to produce a score, the score would be determined as follows:

$$score(i) = \sum_j m(i,j)$$

In this example if the measure is linear error, the hypothesis with the lowest score is determined as the best score. However, it should be realized that the optimal choice can depend on the type of measure, application and compression algorithm used.

Figure 4 illustrates one embodiment of a circuit to determine the best score. In this embodiment, the error measures, e.g., linear error 0-5 are respectively input to function G[·]0 to G[·]5 405, 407, 409, 411, 413, 415. The minimum score can also be input to functions G[·]0 to G[·]5 and the values output are summed by adder logic 421, 423, 425, 427, 429, 431 to produce scores Score(0) to Score(5). In this embodiment, the minimum value determined by minimum circuit 435 is identified as the best score.

Referring back to **Figure 2**, the best score is input to the selectors 215 and 220 which respectively output decoded data of the selected hypotheses corresponding to the best score and error flags identified with particular portions of the decoded data decoded according to the selected hypothesis.

As noted earlier, if the hypothesis chosen is not correct, subsequent blocks of data will also be incorrectly decoded. This is illustrated with respect to **Figure 5**. Representation 505 illustrates an example of encoding blocks in signal space. For example, representation 505 may be a representation of an image frame which contains blocks of data.

In one embodiment, image 505 shows a plurality of pixels, e.g., 510, 511, 514, 516, 518 which are encoded to produce an encoded bitstream 520. If, for example, block *i* is incorrectly decoded such that the length of the Q codes is not accurate, the error will propagate to subsequent blocks, e.g., blocks i+1, i+2, etc., as the starting points of the subsequent blocks are not correctly identified. As an illustration, bitstream 520 illustrates the correct start point 550 for block *i* and incorrect start point 555 for block i+1.

Whenever the selected hypothesis is wrong, scores are very similar among candidate hypotheses. The threshold point can be selected such that all incorrect recovery results are surely detected. Typically, such a threshold also results in a few false alarms, i.e., some correct recovery results are detected as incorrect (shown as the shaded area in **Figure 6**), and a subsequent error recovery process such as the pixel recovery process below, is used to recover the corresponding pixels. **Figure 6** further illustrates a proper threshold selection.

The thresholds can be empirically determined for a particular application using known data. For example, for 4 bit ADRC encoding, the threshold may be set to approximately a value of 120.

In one embodiment, score distributions in successive recoveries are used to reinforce the error detection decision. Given that the current hypothesis is correct, the recovery start point of a next block or group of blocks in the bitstream is also correct. If the start point is correct, candidate hypotheses for subsequent blocks or groups of blocks will generate pixels that exhibit highly correlated properties with respect to neighboring blocks resulting in large score distributions. If the start point is incorrect, candidate hypotheses for subsequent blocks or group of blocks will generate pixels that are uncorrelated with the neighboring pixels resulting in uncorrelated score distributions.

The score distributions previously computed can therefore be used to flag propagation errors. For example, referring to **Figure 5**, score distribution 550 illustrates the selection of an incorrect hypothesis. As noted above, if an incorrect hypothesis is chosen, the starting points for subsequent blocks may not be correct. Score distributions for subsequent blocks can be used to determine error propagation. For example, score distribution 555 shows the score distribution for block i+1 when the starting point is incorrect and score

distribution 560 shows the score distribution for block i+1 when the starting point is correct.

The likelihood that the hypothesis with the best score is correct may be indicated by the score distribution *sd(i)* among candidate hypotheses. The score distribution can be measured in terms of statistics of various order, including standard deviation, average, median, difference of best score and second best score, difference of best score and average of best scores, etc. A score distribution may be chosen so that the score distribution curve for the correct recovery is completely non-overlapping with the score distribution curve for incorrect recovery.

A measurement criterion can be chosen that is highly sensitive to scoring variation among candidate hypothesis. The optimal choice depends on the measurement and scoring techniques used in conjunction with the parameter, i.e., Qbit and Motion Flag, recovery technique as well as the type of data, for example, audio or video.

For example, if linear error measurements are used in conjunction with simple accumulation based scoring of the linear error measurements, the difference between the best and second best linear error scores may be used as a metric for score distribution. Thus, continuing with the present example, the score distribution for the i-th block or group can be measured as sd(i) = score(second best) - score(best), where score(best) represents the score for the contemplated best hypothesis, and score(second best) represents the score for the contemplated second best hypothesis.

The likelihood that a chosen hypothesis is correct may also be determined based on a compatibility measurement. One embodiment of this concept may utilize the decoded domain square error measurement. Pixels belonging to a localized block are highly correlated with neighboring pixels,

and as a result, the square error measurement may yield a low value, although in general, the higher the dynamic range, the higher the square error. However, for a given dynamic range, an incorrect hypothesis results in a much higher square error measurement than that resulting from a correct hypothesis. Thus, the ratio of square error measurement and dynamic range can be alternatively used in place of the score distribution measurement sd.

As noted earlier, the error detection process based on score distribution measurements sd(i) for a block or group i can be reinforced by combining the score distribution measurements of the successive blocks in the bitstream, e.g., i + 1, i + 2...i + W, where W is a length of what is referred to herein as reinforcement window. In one embodiment when groups of 3 blocks are processed together, W may be equal to 2. Other values of W may be selected depending upon the application and performance desired.

Figure 7 shows a typical score distribution sd of successive blocks or groups (referred to herein collectively as block units) following recovery for the i-th block unit. If the current recovery result for block i is incorrect, recovery start points of all successive blocks (i + 1...i + W) within the reinforcement window W becomes incorrect and as a consequence, the corresponding score distribution measurements are small. If the current recovery result is correct, score distribution measurements of successive block units are large. Therefore, score distributions or successive units within a predetermined reinforcement window can be combined to generate an integrated robust measurement for error propagation detection.

Several schemes can be employed for combining successive score distribution measurements, including empirically weighted averaging within the reinforcement window, or simple addition of score distribution measurements within the window.

For example, if the combined score for unit i is:

$$comb\_sd(i) = \sum_{j=0}^{W} sd(i+j) \leq comb\_thr,$$

the recovery result is detected as an incorrect one if the current score sd(i) is less than or equal to a threshold value ind-thr and comb_thr is a preset threshold value for multiple block units within the reinforcement window.

As noted earlier, the threshold values may be empirically determined. For example, the individual threshold may be a value of approximately 120, and the combined threshold may be a value of approximately 800 when W=2.

Alternately, a majority decision can be employed. For example, if:

$$comb\_sd(i) = \sum_{j=0}^{W} \min\left(1, \max\left(0, sd(i+j) - \tau(j)\right)\right)$$

is less than W/2, the recovery result is marked as an incorrect one. $\tau(j)$ is a constant or variable threshold within the reinforcement window. In one embodiment, $\tau(j)$ is a predetermined constant that increases in value according to the block number in the block sequence being examined. For example, for 3-block units, $\tau(0)$ may be approximately equal to 120, $\tau(1)$ may be approximately equal to 200 and $\tau(2)$ may be approximately equal to 300.

Other methods of combining the information of a plurality of blocks or groups of blocks can also be used.

Figure 8 is one embodiment of a circuit for error propagation estimation. The scores for a particular block are evaluated to determine the best and second best score. This is determined by circuits 805 and 810. The difference between the best and second best score is determined by element 815. The scores are then temporarily stored in registers 820, 825, so as to accumulate scores in the present embodiment for a group of three blocks within a reinforcement

window of length 3. The difference values are then summed to perform by adder 830 to produce a combined value which is compared to the combined threshold 840 by comparator 845. If the threshold is not exceeded, an error flag is raised which is then combined by OR gate logic 850 with other error flags which may have been previously determined to generate the pixel error flags that indicate that a pixel recovery process is required for these particular pixels.

Figure 9 illustrates one embodiment of a process for recovering data, and in particular for detecting error propagation in a bitstream of data. At step 905 the start point of a block or group of blocks is identified. If an error is found in the bitstream corresponding to that start point, a recovery process is initiated to provide candidate decodings. For example, in one embodiment candidate decodings of Motion Flag and Qbit data may be generated based upon specified parameters. At step 920, each hypothesis is scored and the candidate with the best score is selected, step 925. The score distribution sd, is measured.

At step 935, if the error flag, DetectErrorFlag, is set, then the score distribution is combined with a prior combined score distribution variable comb_sd, and a counter (j) is incremented, step 950. Thus the combined score distribution comb_sd is generated for a predetermined number of blocks within the reinforcement window W.

The combined score distribution value is then compared to a combined threshold value comb_thr to determine whether subsequent blocks require pixel recovery as the error in a previous block has caused error propagation to occur in the subsequent blocks. At step 940, if an individual score distribution is within a range defined by the threshold value, e.g., does not exceed the individual threshold value, the error flag is set, step 945. Further, a sum of subsequent score distributions is generated and a counter maintained to sum

up the score distributions for W blocks or groups of blocks within the reinforcement window, step 955.

Once the combined score distribution has been generated for the number of blocks within the reinforcement window, at step 960, the combined score distribution is compared to the combined threshold value comb_thr. If a combined score distribution is not within the range defined by the threshold value, e.g., exceeds or equals the combined threshold value, the error flag and counter are reset and the next block is examined, steps 965, 905. This is indicative of the fact that error propagation did not occur and pixel recovery is not required for those blocks. However, if the combined score distribution is within the range, e.g., less than the combined threshold, step 960, error propagation flags are set for remaining undecoded pixels, step 970. The error propagation flags are optionally combined with other error flags, step 974, and pixel error recovery processing is performed on the error flagged pixels, step 978.

One embodiment of the process is illustrated in **Figure 10**. **Figure 10** performs steps 1005, 1010, 1015, 1020, 1025, 1030, 1035, 1040, 1045, 1050, 1055, 1060, 1065, that are similar to those steps discussed above with respect to **Figure 9**. In addition, the process as set forth in **Figure 10** marks the past W blocks for pixel recovery if the combined score distribution is within the range defined by the combined threshold value, step 1070. If there are more blocks to process, the error flag and the counter are reset and the next block examined, step 1075 and 1005. Pursuant to steps 1075 and 1080, pixel error recovery is performed on those pixels with associated error flags set, step 1075, is optional. Thus, in one embodiment a pixel recovery process is performed on pixel errors flagged due to error propagation.

The embodiment set forth in **Figure 10** allows for those instances where the start points may naturally realign even though earlier blocks contained erroneous start points. Thus, pixel recovery will only be applied to those blocks or groups of blocks that have been examined and determined in the range defined by the threshold.

As noted above, once the error flags are set, whether due to error propagation or earlier error detection, a pixel recovery process is performed (e.g., steps 978 **Figure 9**, step 1080 **Figure 10**). In one embodiment, neighboring blocks are used to recover pixels or pixel data contained in erroneous blocks. For example, classified adaptive error recovery processing can be used to generate the pixels using available neighboring pixels. This is disclosed in U.S. Patent No. 5,469,216, which is incorporated herein by reference. Alternately, a classified adaptive error recovery process such as is explained below may be used.

Classification with respect to a deteriorated input signal, e.g., a signal containing lost/damaged data, is performed according to the input signal characteristics. The correct adaptive filter is prepared for each class prior to error recovery processing. More than one classification method may optionally be used to create the plurality of classes. Created classes may include a motion class, an error class, a spatial activity class, or a spatial class.

Classified adaptive error recovery is the technology which utilizes classified adaptive filter processing. A correct classification with respect to the deteriorated input signal is performed according to the input signal characteristics. An adaptive filter is prepared for each class prior to error recovery processing. A plurality of classes is generated based upon characteristics of the data points. The data points are classified as belonging to one of the plurality of classes and assigned a corresponding signal class. An

undeteriorated signal is output corresponding to the input signal in accordance with the input signal class ID. Block data may be generated from the plurality of data points.

A flow diagram of an embodiment is shown in **Figure 11**. The flow chart of **Figure 11** shows the basic processing stream for generating an undeteriorated signal, i.e., a recovered signal, from the deteriorated input signal which contains lost/damaged data. At step 1115, the preprocessing for peripheral erroneous pixels is performed. For example, an erroneous pixel may be replaced with horizontal neighboring data when there are no horizontal errors. If horizontal errors exist, the erroneous pixel may be replaced with vertical neighboring data. If vertical errors also exist, the erroneous pixel may be replaced with previous frame data.

At step 1117, each classification regarding the deteriorated input signal is executed to generate a class ID. Some class taps are selected adaptively according to another class ID. Multiple classifications may be executed, such as motion classification, error classification, spatial activity classification and spatial classification.

The classification scheme can be defined during system design, where the classification scheme, the number of classes, and other specification are decided for the target data. The design stage may include, among others, considerations of system performance and hardware complexity.

At step 1119, multiple classification generates a multiple class ID with a plurality of class IDs which are generated by various classification at step 1117. At step 1121, filter taps are adaptively selected according to the multiple class ID which is generated at step 1119. At step 1123, the filter tap structure is adaptively expanded according to the multiple class ID which is generated at step 1119. The number of filter coefficients that may be stored can be reduced

by allocating the same coefficient to multiple taps. This process is referred to as filter expansion. At step 1125, filtering with respect to the deteriorated input signal is executed to generate an undeteriorated signal. Filter coefficients are selected adaptively according to the multiple class ID which is generated in step 1119.

For further information regarding classified adaptive error recovery, see U.S. Patent Application Serial No. ______, titled "Classified Adaptive Error Recovery Method and Apparatus", filed concurrently herewith, and is herewith incorporated by reference.

Although the present invention is discussed with respect to image data, the present invention may be used with any form of correlated data, including without limitation photographs or other two-dimensional static images, holograms, or other three-dimensional static images, video or other two-dimensional moving images, three-dimensional moving images, a monaural sound stream, or sound separated into a number of spatially related streams, such as stereo.

Figure 12 shows an example of an audio signal and how it is compatible with the present invention.

An example of audio signal 1201 is monitored at one or more time points t0 - t8. The level of audio signal 1201 at time points t0 - t8 is given by tap points X0 - X8. The dynamic range of the audio signal 1201 is given as the difference between the lowest level tap point X0 and the highest level tap point X4. In addition to dynamic range, the standard deviation, the Laplacian value or the spatial gradient value can be introduced for spatial activity classification.

The invention has been described in conjunction with the preferred embodiment. It is evident that numerous alternatives, modifications, variations

and uses will be apparent to those skilled in the art in light of the foregoing description.

CLAIMS

What is claimed is:

1. A method for recovery of lost/damaged data comprising the steps of:

generating candidate hypotheses of decoding for lost/damaged data within a received bitstream of data;

generating scores for the candidate hypotheses;

selecting a hypothesis corresponding to a best score from the generated scores;

decoding the lost/damaged data according to the selected hypothesis;

evaluating at least one candidate hypothesis and selectively flagging data based upon the evaluation; and

executing an error recovery process on the flagged data.

2. The method as set forth in claim 1, wherein the step of evaluating comprises examining at least one score distribution of at least one candidate hypothesis.

3. The method as set forth in claim 2, wherein the step of evaluating comprises comparing the score distribution to a threshold.

4. The method as set forth in claim 2, wherein data of the received bitstream of data is divided into a plurality of block units of varying length, the candidate hypotheses indicate the endpoint of at least one block unit, and the step of evaluating is performed across at least a portion of the plurality of block units.

5. The method as set forth in claim 4, wherein data is flagged for the plurality of blocks.

6. The method as set forth in claim 4, wherein a block unit is selected from the group consisting of a block or group of blocks.

7. The method as set forth in claim 4, wherein the block unit is of varying lengths.

8. The method as set forth in claim 1, wherein:

the received data is divided into a plurality of block units;

the selected candidate hypothesis indicating the endpoint of at least one block unit; and

the step of evaluating comprising evaluating combined candidate hypotheses for at least a portion of the plurality of block units.

9. The method as set forth in claim 8, wherein the step of evaluating comprises generating a combined score distribution.

10. The method as set forth in claim 9, wherein the step of evaluating comprises comparing the combined score distribution to a combined threshold.

11. The method as set forth in claim 2, wherein the score distribution is determined according to a difference function between values derived from the scores of the candidate hypotheses.

12. The method as set forth in claim 2, wherein the score distribution is determined according to the difference between a best score of scores of the candidate hypotheses and a second best score of the scores of candidate hypotheses.

13. The method as set forth in claim 1, wherein the bitstream comprises data selected from the group consisting of correlated data, image data and audio data.

14. The method as set forth in claim 1, wherein the bitstream comprises image data and the error recovery process comprises a pixel error recovery method.

15. The method as set forth in claim 10, wherein the bitstream comprises image data divided into a plurality of blocks and the error recovery process comprises a pixel error recovery process that uses neighboring block information to recover pixel data of flagged data.

16. An apparatus for recovery of lost/damaged data comprising:

a data recovery circuit configured to generate candidate hypotheses for lost/damaged data within a received bitstream of data, generate scores for the candidate hypotheses, select a hypotheses corresponding to a best score from the generated scores and decode the lost/damaged data according to the selected hypothesis;

an error propagation detection circuit coupled to the data recovery circuit, the error propagation circuit configured to selectively flag data based upon an evaluation of the candidate hypotheses; and

an error recovery circuit coupled to the data recovery circuit and the error propagation detection circuit, the error recovery circuit configured to execute error recovery on the flagged data.

17. The apparatus as set forth in claim 16, wherein the error propagation circuit performs an evaluation by examining at least one score distribution corresponding to the candidate hypotheses.

18. The apparatus as set forth in claim 17, wherein the error propagation circuit performs an evaluation by comparing the score distribution to a threshold.

19. The apparatus as set forth in claim 16, wherein the bitstream comprises image data and the error recovery method comprises a pixel error recovery method.

20. The apparatus as set forth in claim 16, wherein the bitstream comprises image data divided into blocks and the error recovery method comprises a pixel error recovery method that uses neighboring block information to recover pixel data of flagged data.

21. The apparatus as set forth in claim 17, wherein received data is divided into a plurality of block units, the candidate hypotheses indicating the endpoint of at least one block unit, the score distribution assembled across at least a portion of the plurality of block units.

22. The apparatus as set forth in claim 21, wherein the error propagation detection circuit flags the data in the plurality of blocks for which an error recovery method is required.

23. The apparatus as set forth in claim 21, wherein a block unit is selected from the group consisting of a block or group of blocks.

24. The apparatus as set forth in claim 21, wherein the received data is divided into a plurality of block units, the selected candidate hypothesis indicating the endpoint of at least one block unit and the evaluation comprising an evaluation of combined candidate hypotheses for at least a portion of the plurality of block units.

25. The apparatus as set forth in claim 24, wherein the evaluation comprises a combined score distribution using score distributions corresponding to at least a portion of the plurality of block units.

26. The apparatus as set forth in claim 25, wherein the evaluation further comprises a comparison of the combined score distribution to a combined threshold.

27. The apparatus as set forth in claim 17, wherein the score distribution is determined according to the difference between a best score of scores of the candidate hypotheses and a second best score of the scores of candidate hypotheses.

28. The apparatus as set forth in claim 16, wherein the bitstream comprises data selected from the group consisting of correlated data, image data and audio data.

29. The apparatus as set forth in claim 16, wherein the data recovery circuit and error propagation detection circuit comprises circuitry selected from the group consisting of logic circuits and a processor.

30. A computer readable medium comprising instructions, which when executed in a processing system, cause the system to perform the steps for data recovery of lost/damaged data, comprising:

generating candidate hypotheses of decoding for lost/damaged data within a received bitstream of data;

generating scores for the candidate hypotheses;

selecting a hypothesis corresponding to a best score from the generated scores;

decoding the lost/damaged data according to the selected hypothesis;

evaluating the candidate hypotheses and selectively flagging data based upon the evaluation; and

executing an error recovery process on the flagged data.

31. The computer readable medium as set forth in claim 30, wherein evaluating comprises examining at least one score distribution of at least one candidate hypothesis.

32. The computer readable medium as set forth in claim 31, wherein evaluating comprises comparing the score distribution to a threshold.

33. The computer readable medium as set forth in claim 30, wherein the data of the received bitstream of data is divided into a plurality of block units of varying length, the candidate hypotheses indicate the endpoint of at least one block unit, and the step of evaluating is performed across at least a portion of the plurality of block units.

34. The computer readable medium as set forth in claim 33, wherein data is flagged for the plurality of blocks.

35. The computer readable medium as set forth in claim 33, wherein a block unit is selected from the group consisting of a block or group of blocks.

36. The computer readable medium as set forth in claim 30, wherein:

the received data is divided into a plurality of block units;

the selected candidate hypothesis indicating the endpoint of at least one block unit; and

the step of evaluating comprising evaluating combined candidate hypotheses for at least a portion of the plurality of block units.

37. The computer readable medium as set forth in claim 36, wherein the step of evaluating comprises generating a combined score distribution.

38. The computer readable medium as set forth in claim 37, wherein the step of evaluating comprises comparing the combined score distribution to a combined threshold.

39. The computer readable medium as set forth in claim 30, wherein the bitstream comprises data selected from the group consisting of correlated data, image data and audio data.

40. An apparatus for recovery of lost/damaged data comprising the steps of:

means for generating candidate hypotheses of decoding for lost/damaged data within a received bitstream of data;

means for generating scores for the candidate hypotheses;

means for selecting a hypothesis corresponding to a best score from the generated scores;

means for decoding the lost/damaged data according to the selected hypothesis;

means for evaluating the candidate hypotheses and selectively flagging data based upon the evaluation; and

means for executing an error recovery process on the flagged data.

41. A method for recovery of data comprising the steps of:

generating candidate hypotheses for lost/damaged data within a received bitstream of data;

assembling at least one score distribution using candidate hypotheses; and

selectively flagging data that an error recovery method is required for based upon the score distribution.

42. The method as set forth in claim 41, wherein data of the received bitstream of data is divided into a plurality of block units of varying length, the

candidate hypotheses indicate the endpoint of at least one block unit, and the score distribution is assembled across at least a portion of the plurality of block units.

43. The method as set forth in claim 42, wherein the step of flagging selectively flags the data in the plurality of blocks for which an error recovery method is required.

44. The method as set forth in claim 2, wherein a block unit is selected from the group consisting of a block or group of blocks.

45. The method as set forth in claim 1, wherein the received data is divided into a plurality of block units, the candidate hypotheses indicate the endpoint of at least one block unit, the step of assembling comprising the step of if a score distribution for a block unit of the plurality of block units is within a range defined by an individual threshold, generating a combined score distribution of the score distributions for at least a portion of the plurality of block units; and the step of flagging comprising the step of if the combined score distribution is within a range defined by a combined threshold, flagging that an error recovery method is required for the at least a portion of the plurality of block units.

46. The method as set forth in claim 41, wherein the score distribution is determined according to a difference function between values derived from the scores of the candidate hypotheses.

47. The method as set forth in claim 41, wherein the score distribution is determined according to the difference between a best score of scores of the candidate hypotheses and a second best score of the scores of candidate hypotheses.

48. The method as set forth in claim 41, wherein the bitstream comprises data selected from the group consisting of correlated data, image data and audio data.

49. The method as set forth in claim 41, further comprising the step of performing an error recovery method for flagged data.

50. The method as set forth in claim 49, wherein the bitstream comprises image data and the error recovery method comprises a pixel error recovery method.

51. The method as set forth in claim 49, wherein the bitstream comprises image data divided into a plurality of blocks and the error recovery method comprises a pixel recovery method that uses neighboring block information to recover pixel data of flagged data.

52. An apparatus for recovery of data comprising the steps of:

a data recovery circuit configured to generate candidate hypotheses for lost/damaged data within a received bitstream of data and assemble at least one score distribution using candidate hypotheses; and

an error propagation detection circuit coupled to the data recovery circuit, the error propagation detection circuit configured to selectively flag

data that an error recovery method is required for based upon the score distribution.

53. The apparatus as set forth in claim 52, further comprising an error recovery circuit coupled to the error propagation detection circuit, the error recovery circuit configured to generate an error recovery method for flagged data.

54. The apparatus as set forth in claim 53, wherein the bitstream comprises image data and the error recovery method comprises a pixel error recovery method.

55. The apparatus as set forth in claim 53, wherein the bitstream comprises image data divided into blocks and the error recovery method comprises a pixel error recovery method that uses neighboring block information to recover pixel data of flagged data.

56. The apparatus as set forth in claim 53, wherein received data is divided into a plurality of block units of varying length, the candidate hypotheses indicating the endpoint of at least one block unit, the score distribution assembled across the plurality of block units.

57. The apparatus as set forth in claim 56, wherein the error propagation detection circuit flags the data in the plurality of blocks for which an error recovery method is required.

58. The apparatus as set forth in claim 52, wherein received data is divided into a plurality of block units, the candidate hypotheses indicating the endpoint of at least one block unit, the error propagation detection circuit further configured to:

generate a combined score distribution of the score distributions for at least a portion of the plurality of block units if a score distribution for a block unit of the plurality of block units is within a range defined by an individual threshold; and

selectively flag that an error recovery method is required for the at least a portion of the plurality of block units if the combined score distribution is within a range defined by a combined threshold.

59. The apparatus as set forth in claim 52, wherein the score distribution is determined according to a difference function between values derived from the scores of the candidate hypotheses.

60. The apparatus as set forth in claim 52, wherein the score distribution is determined according to the difference between a best score of scores of the candidate hypotheses and a second best score of the scores of candidate hypotheses.

61. The apparatus as set forth in claim 52, wherein the bitstream comprises data selected from the group consisting of correlated data, image data and audio data.

62. The apparatus as set forth in claim 52, wherein the data recovery circuit and error propagation detection circuit comprises circuitry selected from the group consisting of logic circuits and a processor.

63. A computer readable medium comprising instructions, which when executed in a processing system, causes the system to perform the steps for recovery of data, comprising:

generating candidate hypotheses for lost/damaged data within received data;

assembling at least one score distribution using at least one candidate hypothesis; and

selectively flagging data that an error recovery method is required for based upon the score distribution.

64. The computer readable medium as set forth in claim 63, wherein received data is divided into a plurality of block units of varying length, the candidate hypotheses indicating the endpoint of at least one block unit, the score distribution assembled across the plurality of block units.

65. The computer readable medium as set forth in claim 64, wherein the instruction that, when executed, flags an error recovery method for the data flags an error recovery method for the plurality of blocks.

66. The computer readable medium as set forth in claim 63, wherein received data is divided into a plurality of block units of varying lengths, the candidate hypotheses indicating the endpoint of at least one block unit, the instruction which, when executed, assembles a score distribution comprises if a

score distribution for a block unit of the plurality of block units is within a range defined by an individual threshold, generating a combined score distribution of the score distributions for at least a portion of the plurality of block units; and the instruction, which when executed flags data comprises if the combined score distribution is within a range defined by a combined threshold, flagging that an error recovery method is required for the at least a portion of the plurality of block units.

67. The computer readable medium as set forth in claim 63, wherein the score distribution is determined according to a difference function between values derived from the scores of the candidate hypotheses.

68. The computer readable medium as set forth in claim 63, wherein the bitstream comprises data selected from the group consisting of correlated data, image data and audio data.

69. The computer readable medium as set forth in claim 63, further comprising instructions which, when executed, comprise performing an error recovery method for flagged data.

70. The computer readable medium as set forth in claim 69, wherein the bitstream comprises image data and the error recovery method comprises a pixel error recovery method.

71. An apparatus for recovery of data comprising:

means for generating candidate hypotheses data recovery methods to lost/damaged data;

means for assembling at least one score distribution using at least one candidate hypothesis;

means for selectively flagging that an error recovery method is required based upon the score distribution.

72. A method for recovery of data from a bitstream of data comprising the steps of:

detecting errors in data due to error propagation within the bitstream of data; and

performing a data error recovery process on data with detected errors.

73. The method as set forth in claim 72, wherein the bitstream comprises data selected from the group consisting of correlated data, image data and audio data.

74. The method as set forth in claim 72, wherein the step of detecting comprises the steps of:

generating candidate hypotheses for lost/damaged data within a received bitstream of data;

assembling a score distribution using candidate hypotheses; and

if the score distribution is within a range defined by a threshold, detecting an error.

75. The method as set forth in claim 72, wherein the bitstream of data comprises image data and the step of performing a data error recovery process on data comprises using a pixel error recovery process.

76. The method as set forth in claim 75, wherein the pixel error recovery process comprises a classified adaptive pixel error recovery process.

78. The method as set forth in claim 72, further comprising the step of receiving error flags indicative of errors with respect to data of the bitstream, said step of performing a data error recovery process further comprising performing the data error recovery process on the data corresponding to received error flags.

79. The method as set forth in claim 72, wherein the step of performing a data error recovery process is performed on at least one block unit of data.

80. The method as set forth in claim 72, further comprising the steps of:

decoding at least a portion of the bitstream of data;

preventing data degradation by performing a block unit recovery process on the decoded data in block units in which errors due to error propagation are detected, said step of preventing performed prior to the step of performing a data error recovery process.

81. An apparatus for recovery of data from a bitstream of data comprising the steps of:

a data recovery circuit configured to generate candidate hypotheses for lost/damaged data within a received bitstream of data;

an error propagation detection circuit coupled to the data recovery circuit, said error propagation detection circuit configured to detect errors in data due to error propagation within the bitstream of data; and

an error recovery circuit coupled to the error propagation detection circuit, the error recovery circuit configured to perform a data error recovery process on data with detected errors.

82. The apparatus as set forth in claim 81, wherein the bitstream comprises data selected from the group consisting of correlated data, image data and audio data.

83. The apparatus as set forth in claim 81, wherein the error propagation detection circuit generates candidate hypotheses for lost/damaged data within a received bitstream of data, assembles a score distribution using candidate hypotheses, and detects an error if the score distribution is within a range defined by a threshold.

84. The apparatus as set forth in claim 81, wherein the bitstream of data comprises image data and the error recovery circuit uses a pixel error recovery process.

85. The apparatus as set forth in claim 84, wherein the error recovery circuit uses a classified adaptive pixel error recovery process.

86. The apparatus as set forth in claim 81, further comprising a pixel error flag circuit configured to receive error flags indicative of errors with

respect to data of the bitstream, said error recovery circuit further configured to performing error recovery on the data corresponding to received error flags.

87. The apparatus as set forth in claim 81, wherein the error recovery circuit performs error recovery on at least one block of data.

88. The apparatus as set forth in claim 81, further comprising:

a decoder coupled to receive and decode at least a portion of the bitstream of data;

a data degradation prevention unit coupled to the decoder and the error propagation detection circuit and configured to perform a block unit recovery process on the decoded data in block units in which errors due to error propagation are detected.

89. A computer readable medium comprising instructions, which when executed in a processing system, causes the system to perform the steps for recovery of data, comprising:

detecting errors in data due to error propagation within the bitstream of data; and

performing a data error recovery process on data with detected errors.

90. The computer readable medium as set forth in claim 89, wherein the bitstream comprises data selected from the group consisting of correlated data, image data and audio data.

91. The computer readable medium as set forth in claim 89, wherein detecting comprises:

generating candidate hypotheses for lost/damaged data within a received bitstream of data;

assembling a score distribution using candidate hypotheses; and

if the score distribution is within a range defined by a threshold, detecting an error.

92. The computer readable medium as set forth in claim 89, wherein the bitstream of data comprises image data and performing a data error recovery process on data comprises using a pixel error recovery process.

93. The computer readable medium as set forth in claim 89, further comprising instructions, which when executed performing a process comprising receiving error flags indicative of errors with respect to data of the bitstream, the instructions which when executed perform a data error recovery process further comprising performing the data error recovery process on the data corresponding to received error flags.

94. The computer readable medium as set forth in claim 89, wherein a data error recovery process is applied to at least one block unit of data.

95. The computer readable medium as set forth in claim 94, further comprising instructions, which when executed, perform a process comprising:

decoding at least a portion of the bitstream of data;

preventing data degradation by performing a block unit recovery process on the decoded data in block units in which errors due to error propagation are detected, preventing performed prior to performing a data error recovery process.

96. An apparatus for recovery of data from a bitstream of data comprising the steps of:

means for detecting errors in data due to error propagation within the bitstream of data; and

means for performing a data error recovery process on data with detected errors.

ABSTRACT

The present invention provides a mechanism for preventing quality degradation of decoded data during the decoding of encoded data. In one embodiment, error propagation is detected and corresponding data is flagged. An error recovery process is then applied to the flagged data. In an alternate embodiment, scores for candidate hypotheses are calculated for lost/damaged data. A score distribution is used for detection of the false candidate hypotheses. The data are flagged if their score distribution is within a range defined by a threshold and an error recovery process is applied to recover those data having associated error flags set.

SYSTEM PROPOSAL FOR ERROR RECOVERY

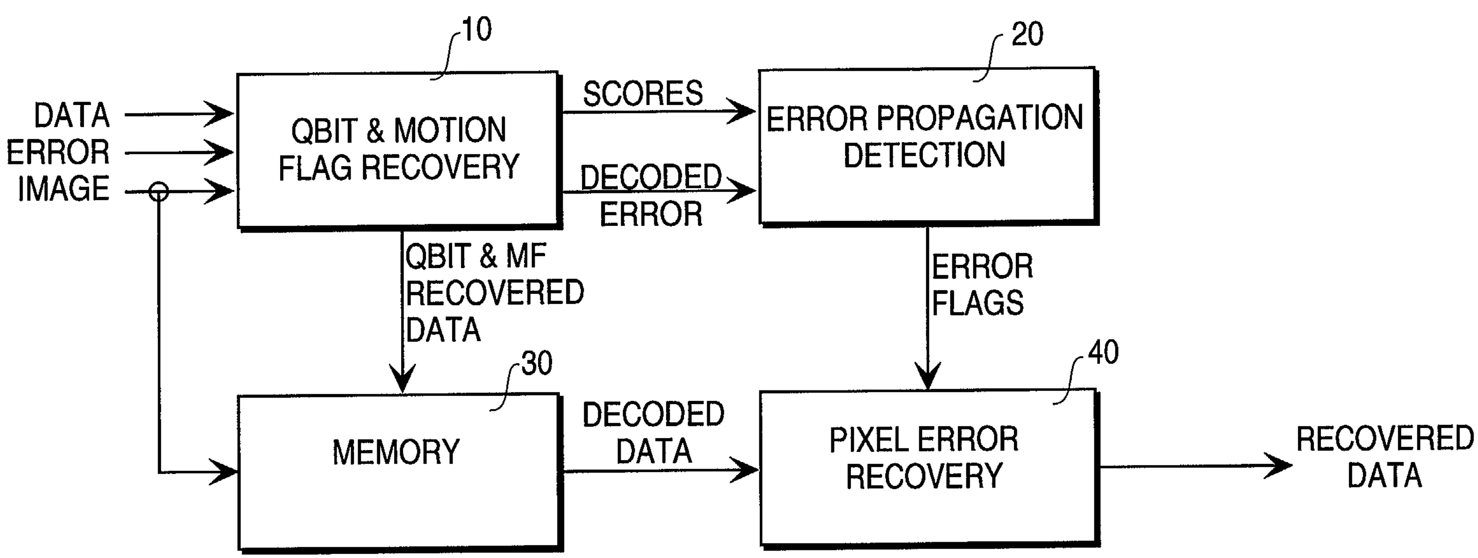

FIG. 1a

09249489 .021299

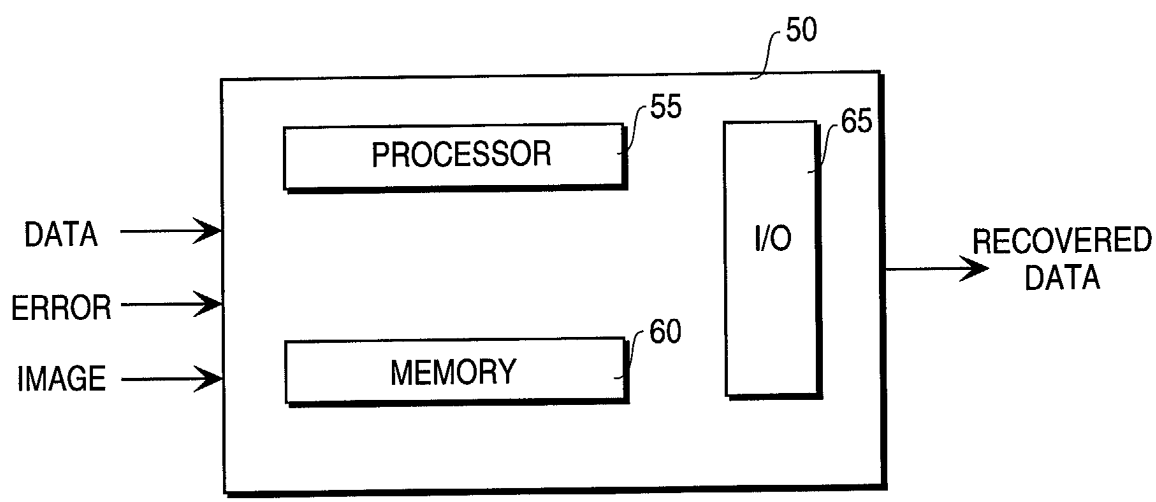
50
PROCESSOR
55
I/O
65
DATA
ERROR
IMAGE
MEMORY
60
RECOVERED DATA

FIG. 1b

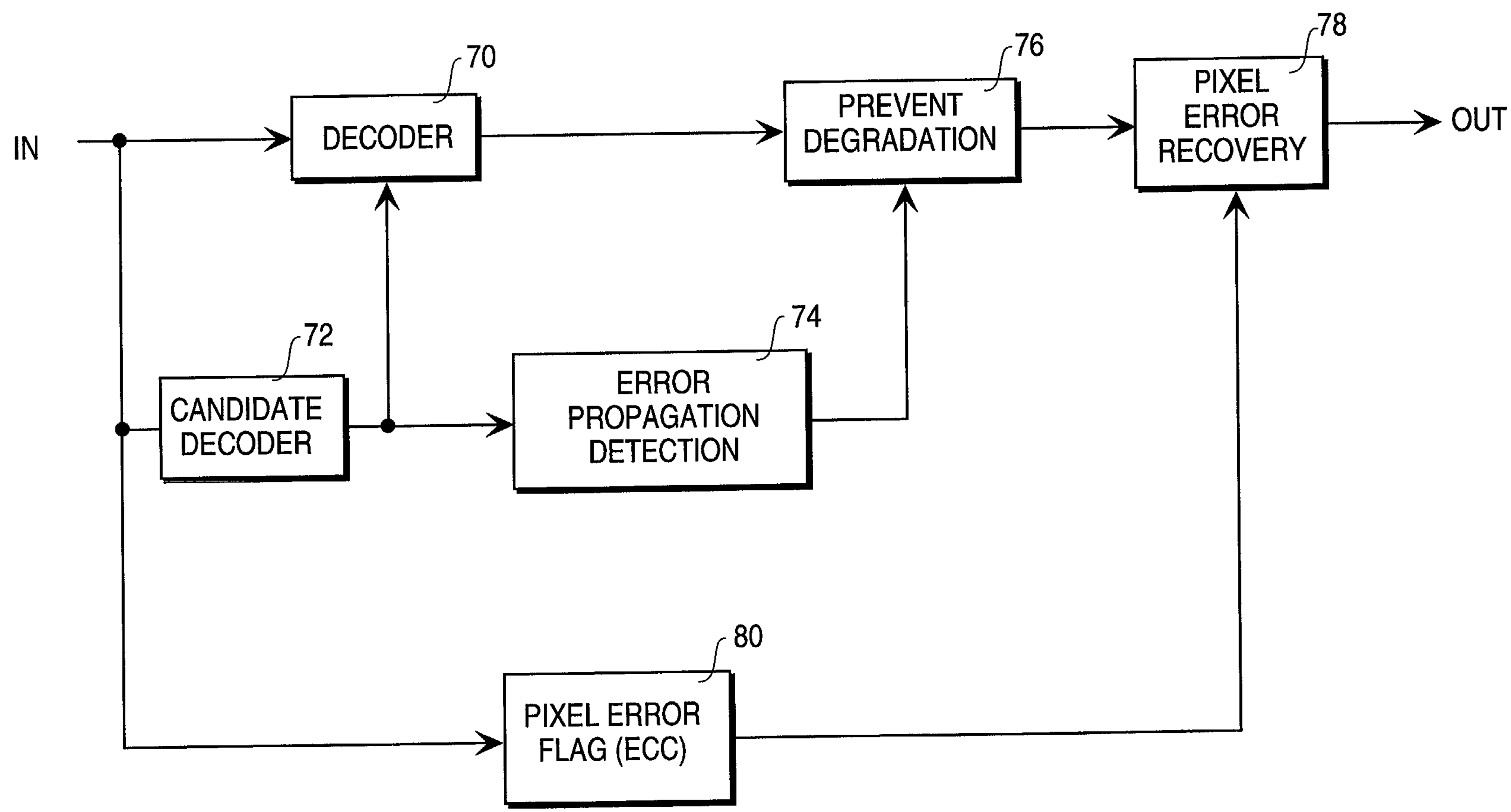
IN
DECODER
70
CANDIDATE DECODER
72
ERROR PROPAGATION DETECTION
74
PREVENT DEGRADATION
76
PIXEL ERROR RECOVERY
78
OUT
PIXEL ERROR FLAG (ECC)
80

FIG. 1c

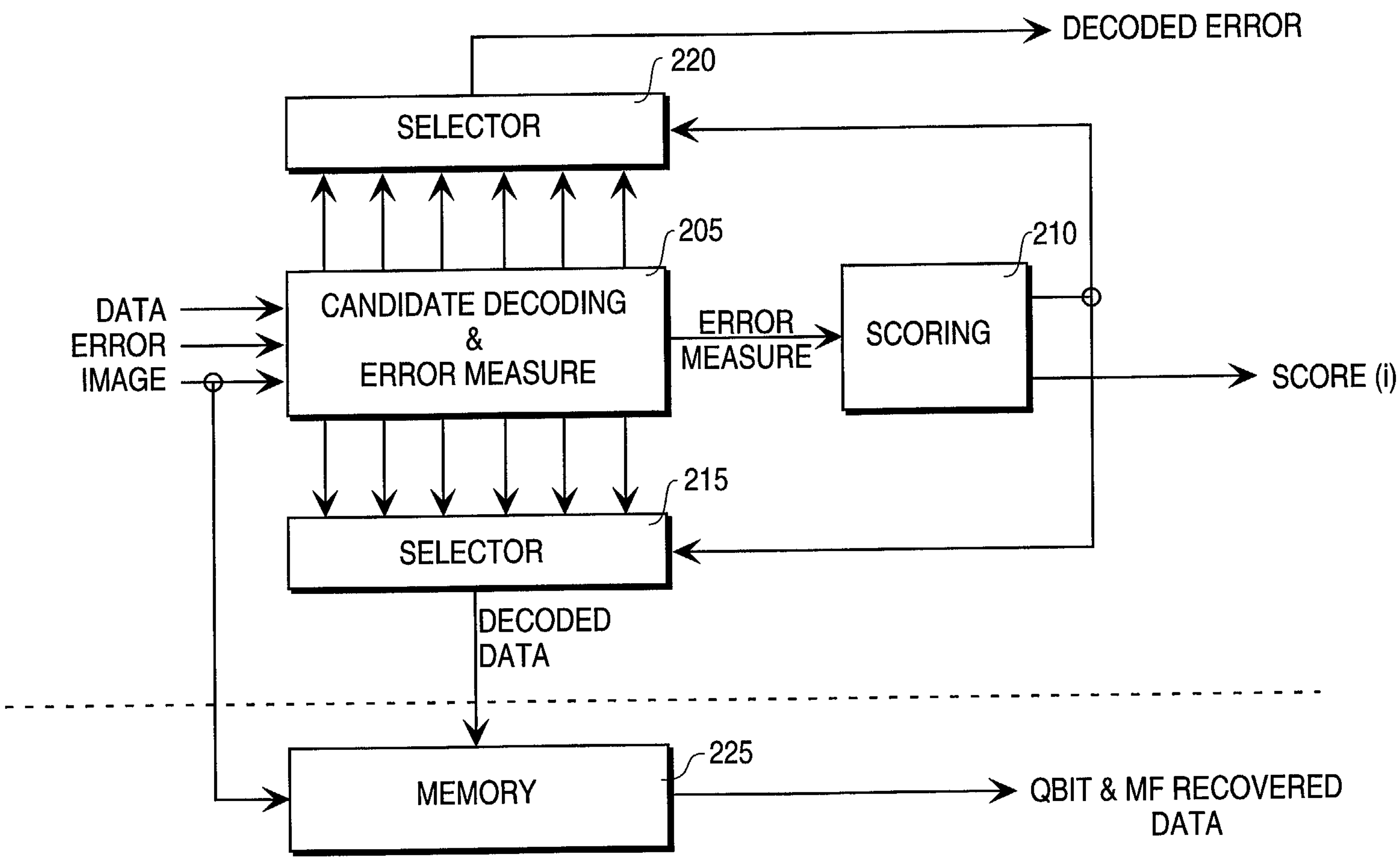
DECODED ERROR
220
SELECTOR
205
210
DATA
ERROR
IMAGE
CANDIDATE DECODING
&
ERROR MEASURE
ERROR
MEASURE
SCORING
SCORE (i)
215
SELECTOR
DECODED
DATA
MEMORY
225
QBIT & MF RECOVERED
DATA

FIG. 2

LINEAR ERROR MEASUREMENT BLOCK DIAGRAM

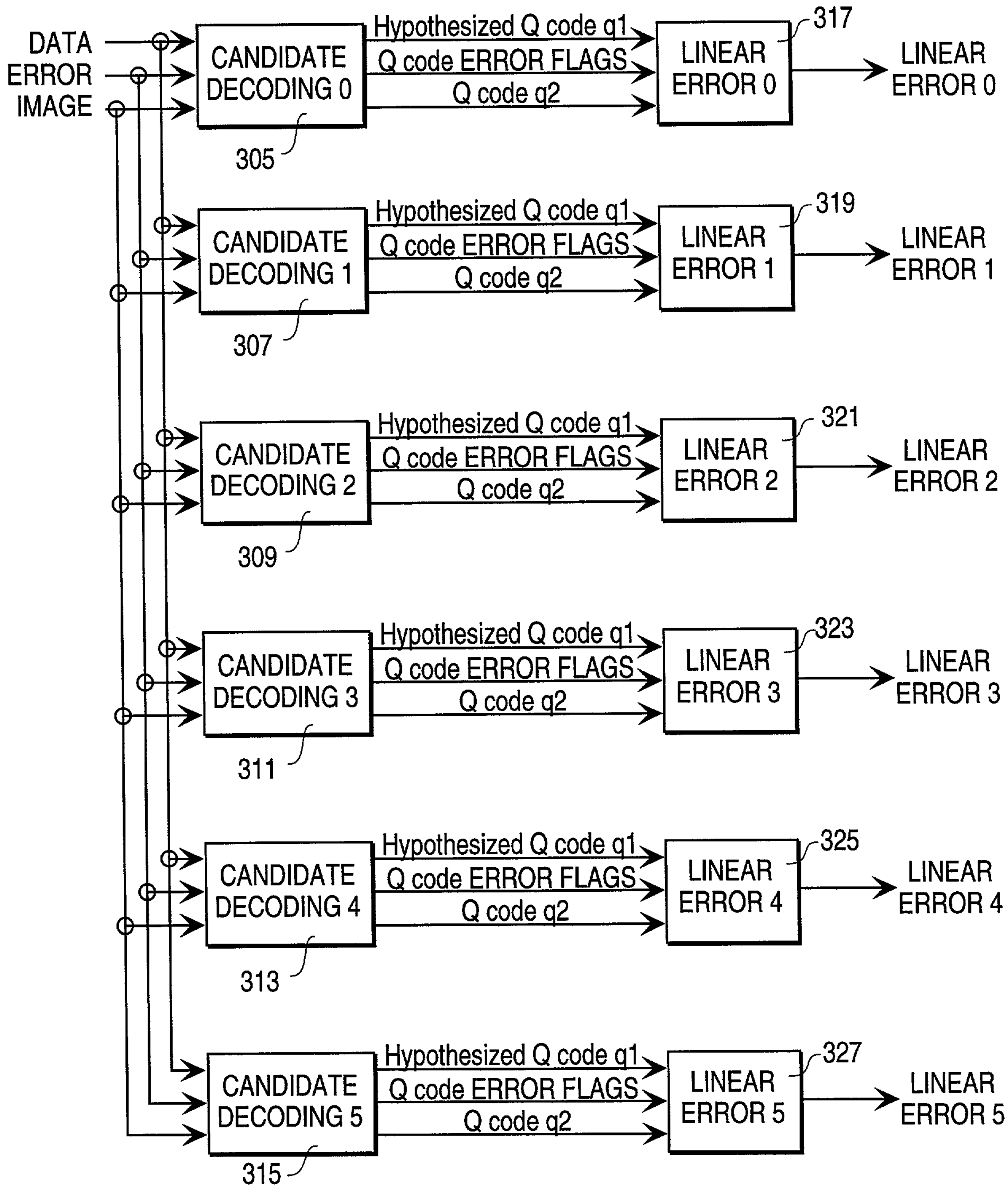

FIG. 3

EXAMPLE OF SCORING PROCESS

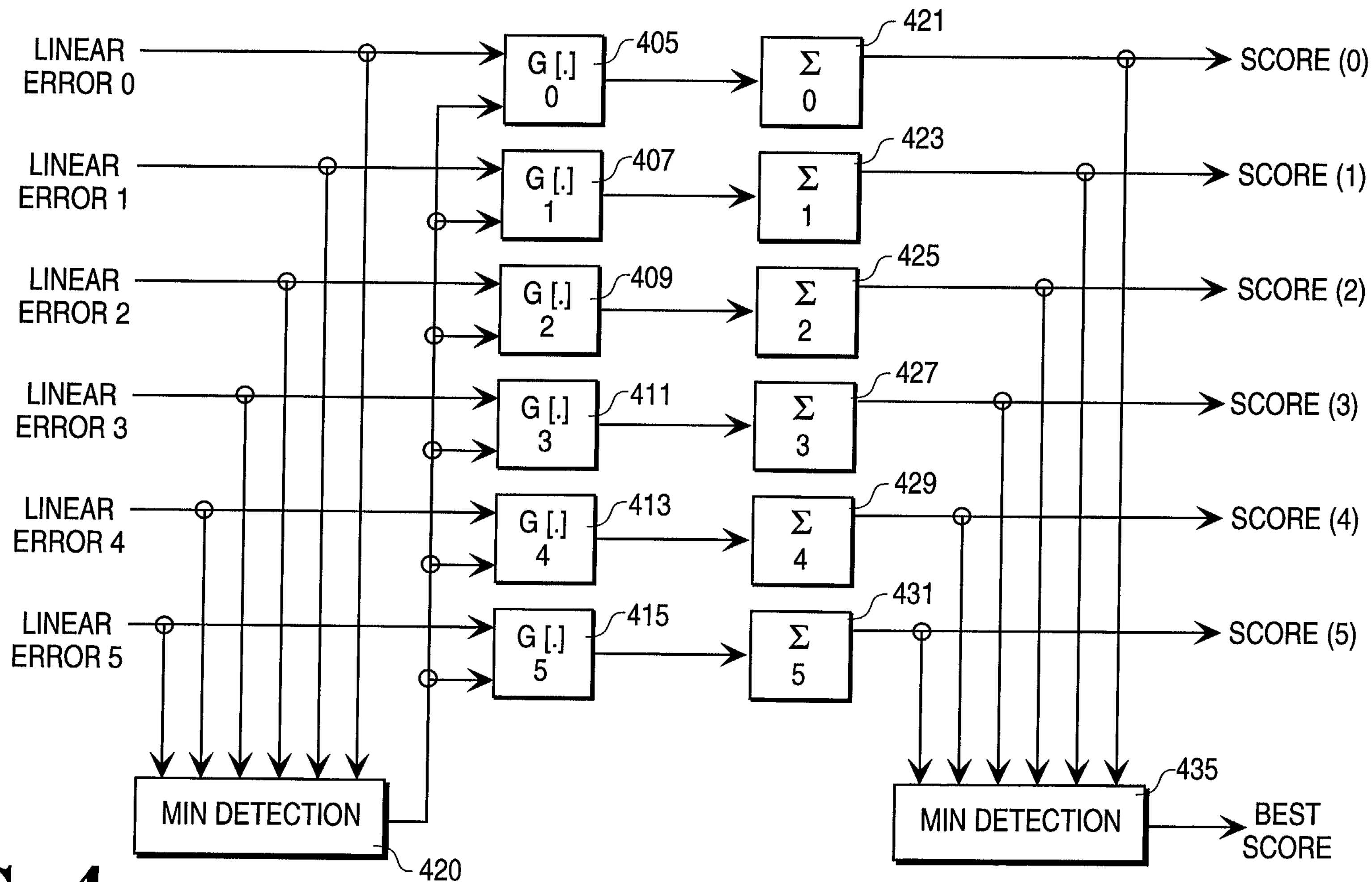

FIG. 4

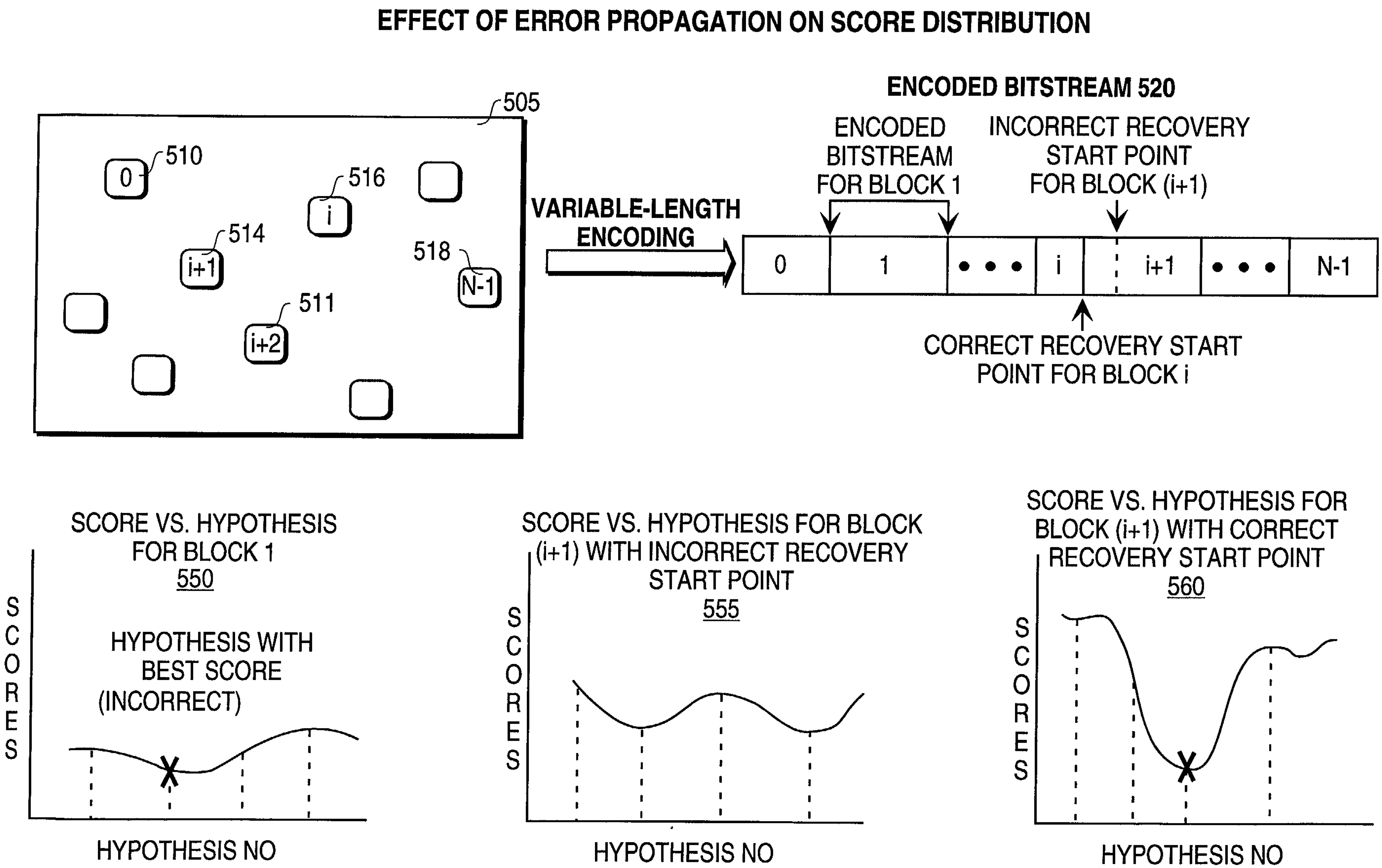
EFFECT OF ERROR PROPAGATION ON SCORE DISTRIBUTION
505
510
0
516
i
514
i+1
518
N-1
511
i+2
VARIABLE-LENGTH ENCODING
ENCODED BITSTREAM 520
ENCODED BITSTREAM FOR BLOCK 1
INCORRECT RECOVERY START POINT FOR BLOCK (i+1)
0
1
• • •
i
i+1
• • •
N-1
CORRECT RECOVERY START POINT FOR BLOCK i
SCORE VS. HYPOTHESIS FOR BLOCK 1
550
HYPOTHESIS WITH BEST SCORE (INCORRECT)
SCORES
HYPOTHESIS NO
SCORE VS. HYPOTHESIS FOR BLOCK (i+1) WITH INCORRECT RECOVERY START POINT
555
SCORES
HYPOTHESIS NO
SCORE VS. HYPOTHESIS FOR BLOCK (i+1) WITH CORRECT RECOVERY START POINT
560
SCORES
HYPOTHESIS NO

FIG. 5

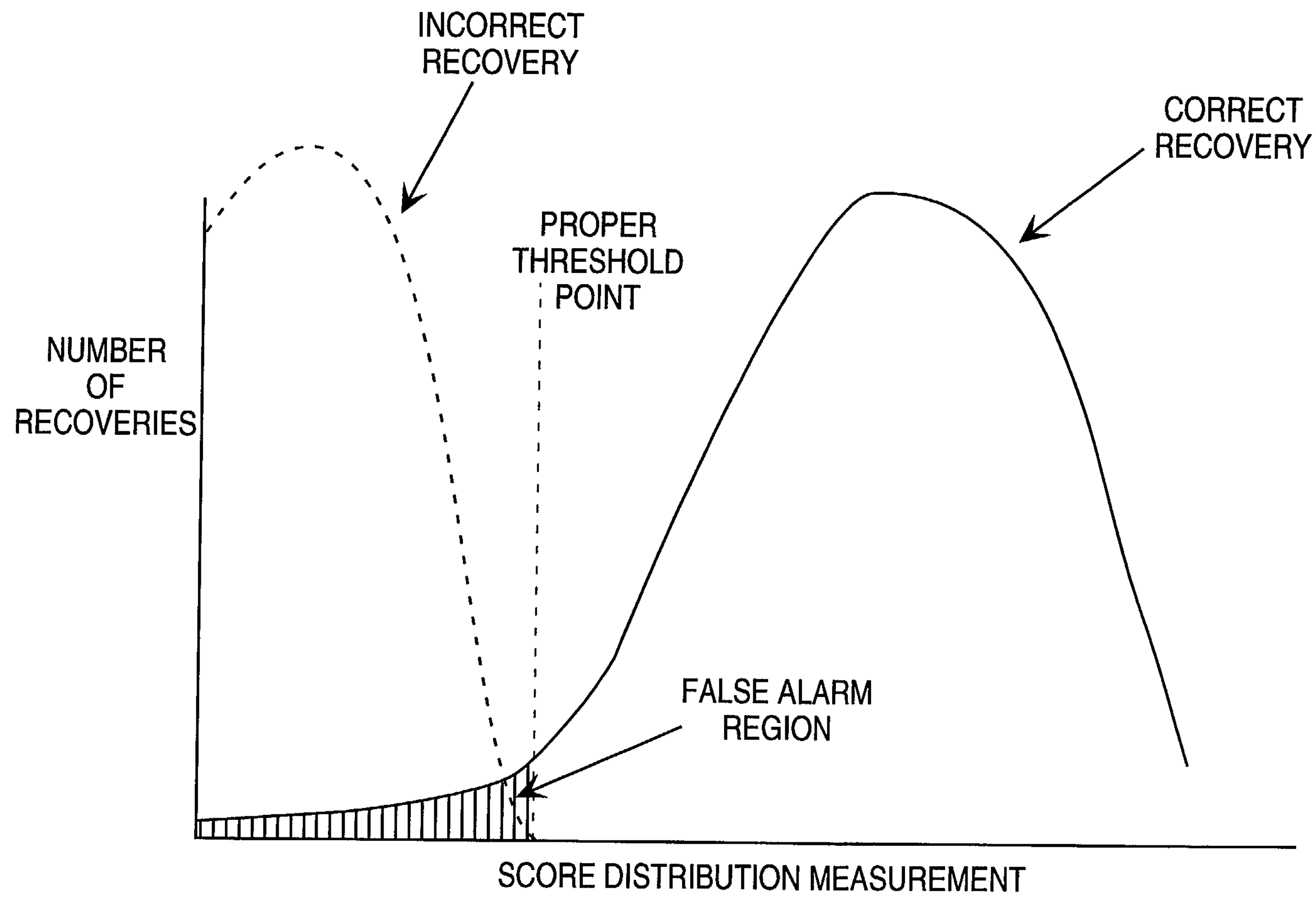
INCORRECT RECOVERY
CORRECT RECOVERY
PROPER THRESHOLD POINT
NUMBER OF RECOVERIES
FALSE ALARM REGION
SCORE DISTRIBUTION MEASUREMENT

FIG. 6

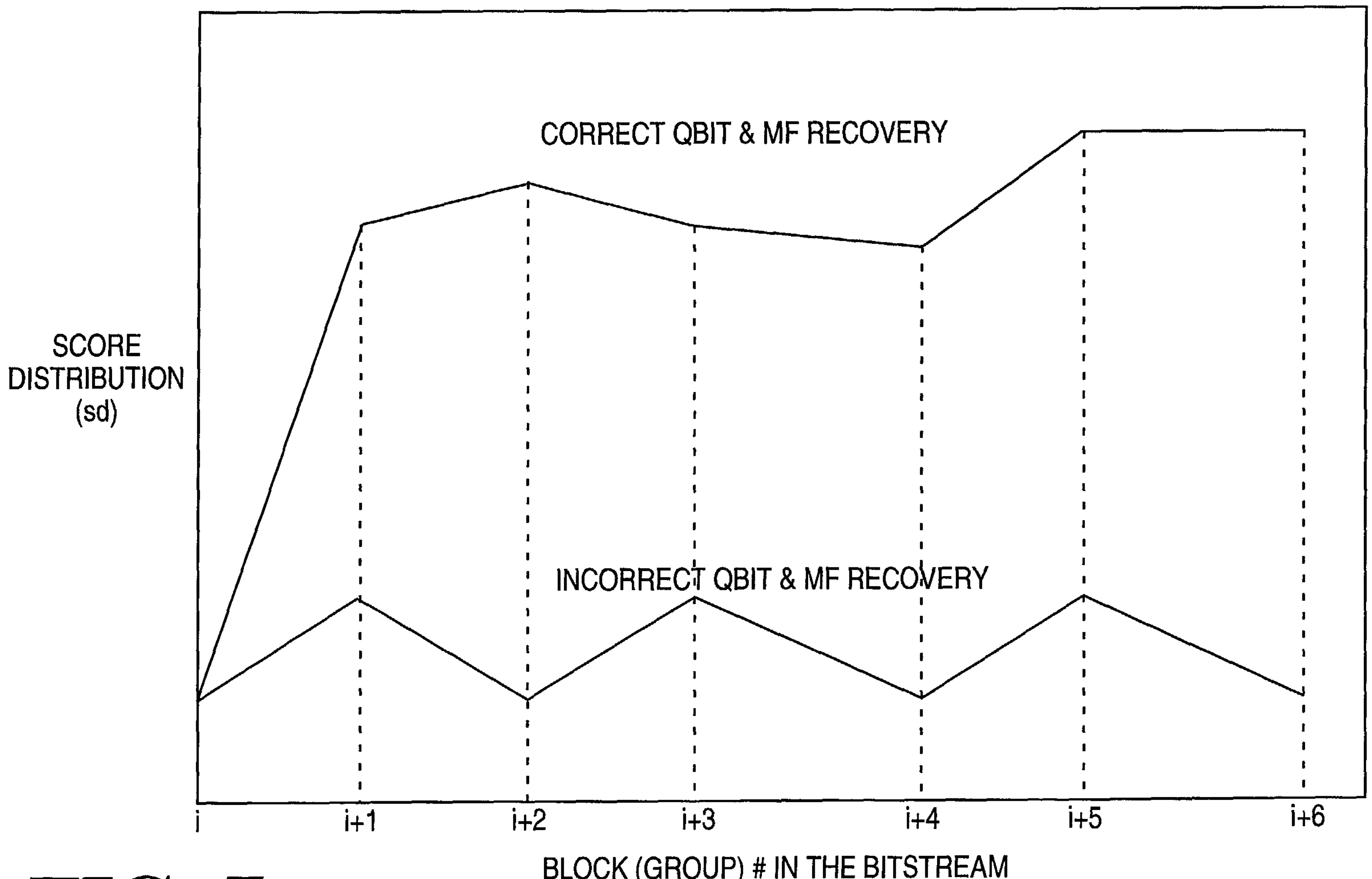
SCORE
DISTRIBUTION
(sd)
CORRECT QBIT & MF RECOVERY
INCORRECT QBIT & MF RECOVERY
i
i+1
i+2
i+3
i+4
i+5
i+6
BLOCK (GROUP) # IN THE BITSTREAM

FIG. 7

ERROR PROPAGATION DETECTION BLOCK CHART

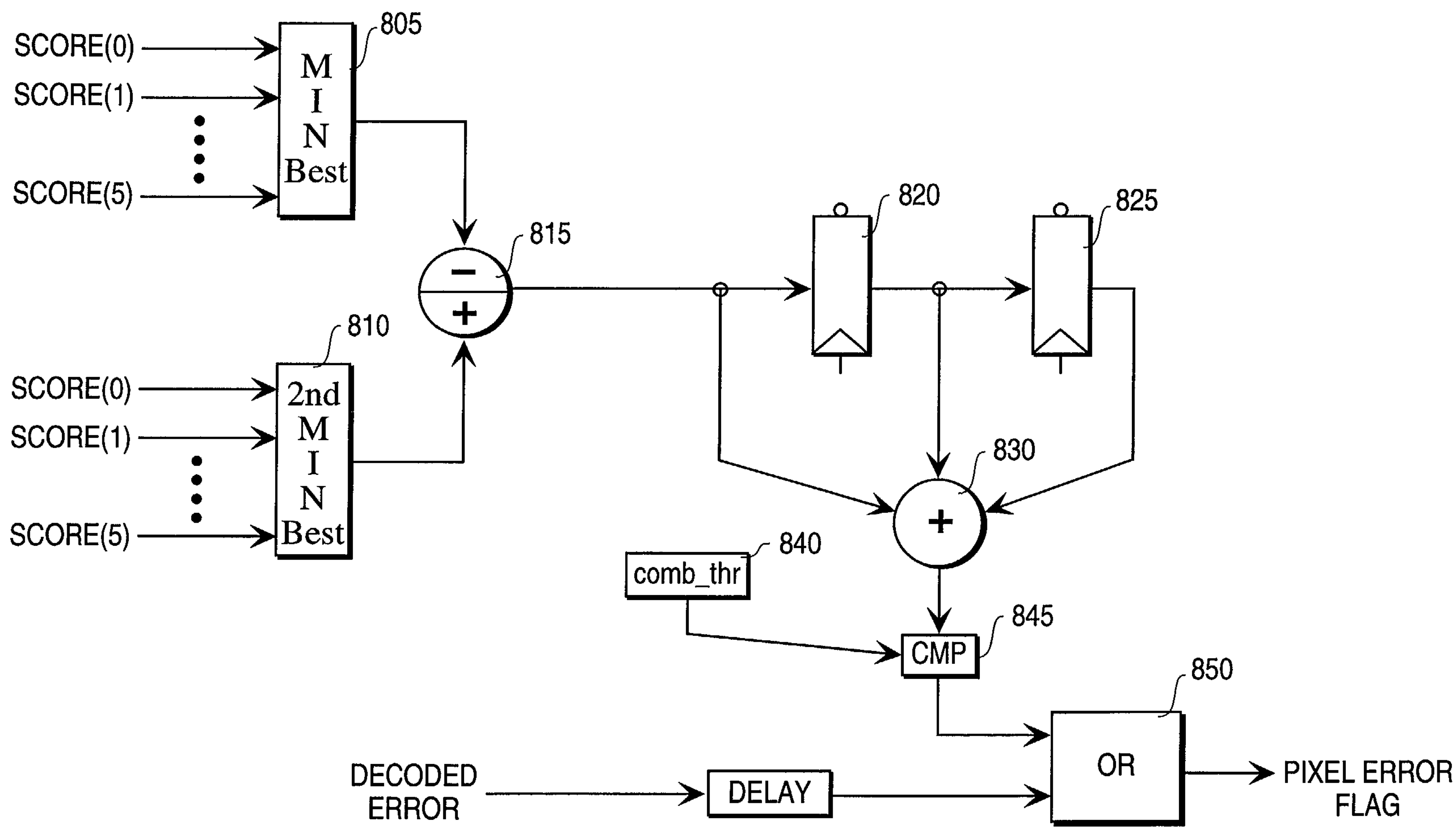

FIG. 8

FLOWCHART FOR ERROR RECOVERY SYSTEM

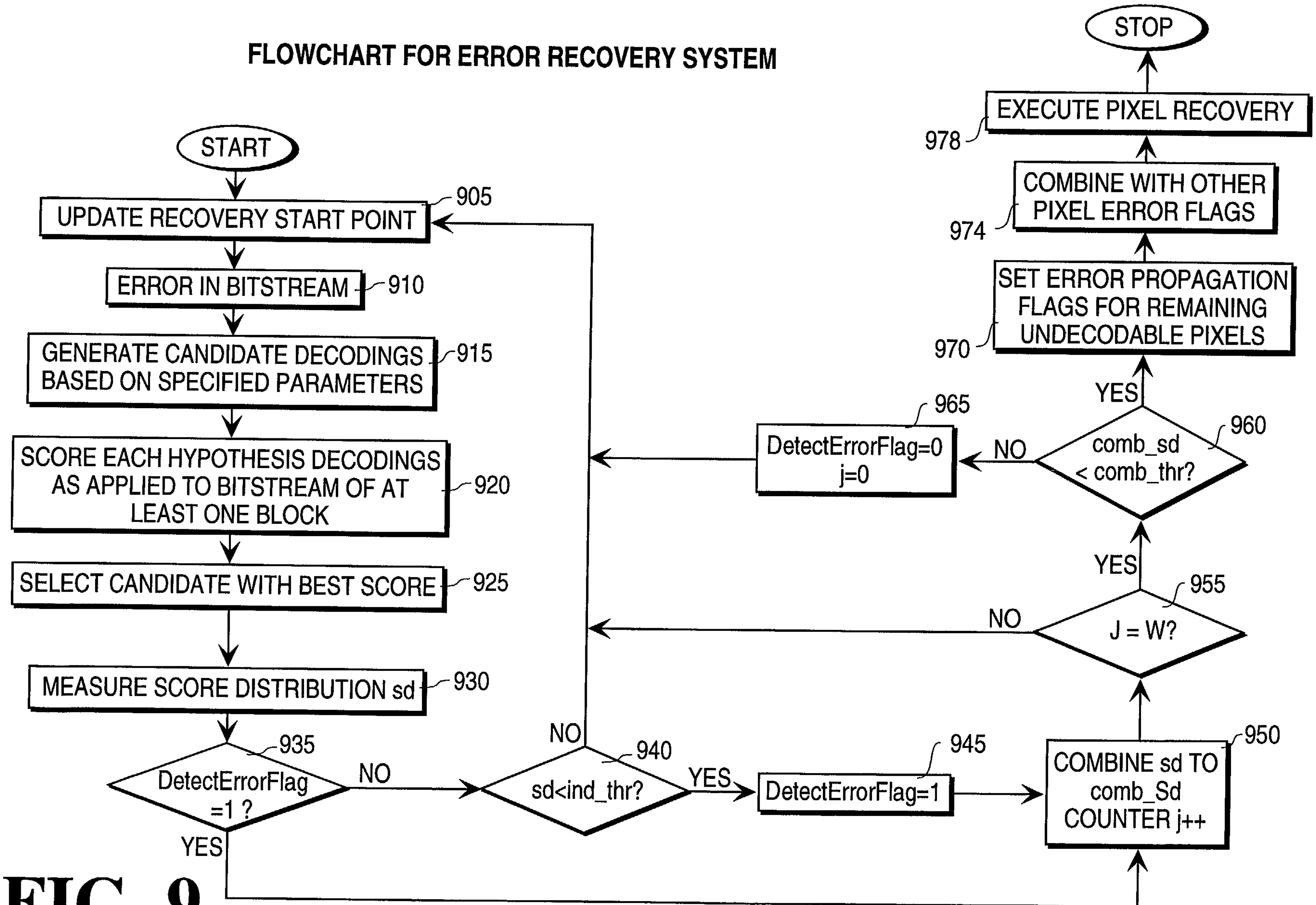

FIG. 9

ERROR RECOVERY WITH REALIGNMENT CAPABILITY

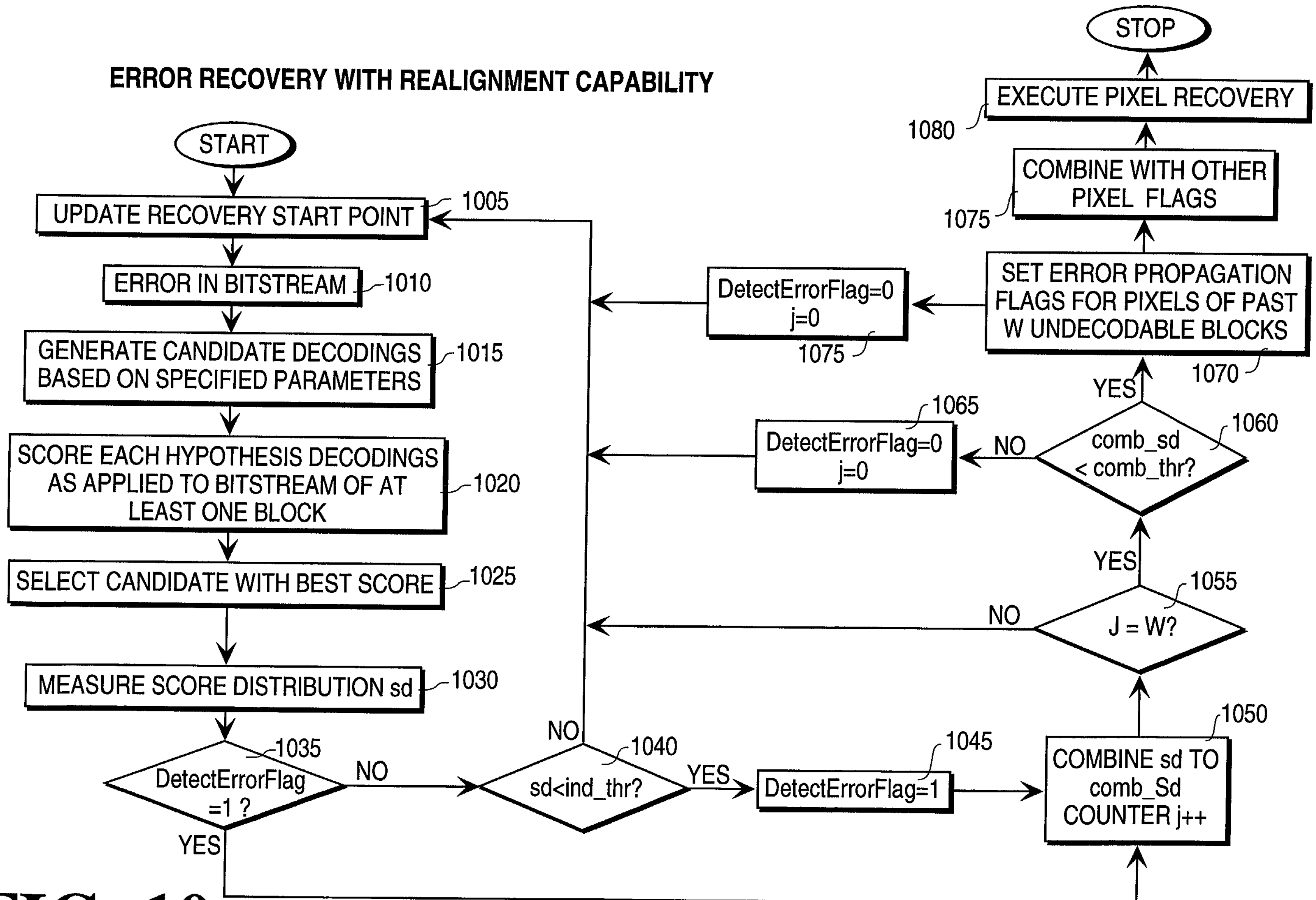

FIG. 10

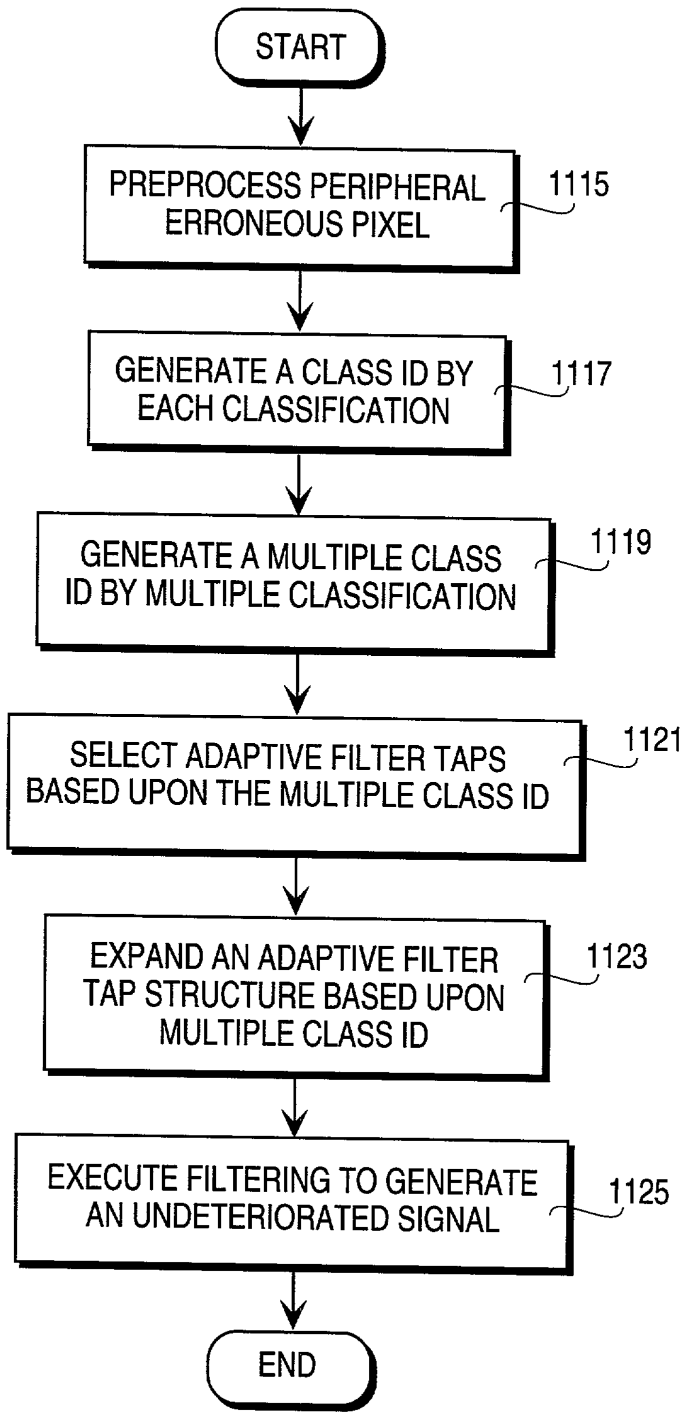
START
PREPROCESS PERIPHERAL ERRONEOUS PIXEL
1115
GENERATE A CLASS ID BY EACH CLASSIFICATION
1117
GENERATE A MULTIPLE CLASS ID BY MULTIPLE CLASSIFICATION
1119
SELECT ADAPTIVE FILTER TAPS BASED UPON THE MULTIPLE CLASS ID
1121
EXPAND AN ADAPTIVE FILTER TAP STRUCTURE BASED UPON MULTIPLE CLASS ID
1123
EXECUTE FILTERING TO GENERATE AN UNDETERIORATED SIGNAL
1125
END

FIG. 11

Attorney's Docket No.: 80398.P198 Patent

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below, next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Method and Apparatus for Error Data Recovery

the specification of which

XXX is attached hereto.

_____ was filed on ____________________ as
United States Application Number ________________
or PCT International Application Number ________________
and was amended on ____________________.
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above. I do not know and do not believe that the claimed invention was ever known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, and that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (for a utility patent application) or six months (for a design patent application) prior to this application.

I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d), of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Priority
Claimed

Prior Foreign Application(s)

(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No

I hereby claim the benefit under title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below

(Application Number)	Filing Date
(Application Number)	Filing Date

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Number)	Filing Date	(Status -- patented, pending, abandoned)
(Application Number)	Filing Date	(Status -- patented, pending, abandoned)

I hereby appoint Farzad E. Amini, Reg. No. P42,261; Aloysius T. C. AuYeung, Reg. No. 35,432; Amy M. Armstrong, Reg. No. 42,265; William Thomas Babbitt, Reg. No. 39,591; Carol F. Barry, Reg. No. 41,600; Jordan Michael Becker, Reg. No. 39,602; Bradley J. Bereznak, Reg. No. 33,474; Michael A. Bernadicou, Reg. No. 35,934; Roger W. Blakely, Jr., Reg. No. 25,831; Gregory D. Caldwell, Reg. No. 39,926; Kent M. Chen, Reg. No. 39,630; Lawrence M. Cho, Reg. No. 39,942; Yong S. Choi, Reg. No. P43,324; Thomas M. Coester, Reg. No. 39,637; Roland B. Cortes, Reg. No. 39,152; Barbara Bokanov Courtney, Reg. No. 42,442; Michael Anthony DeSanctis, Reg. No. 39,957; Daniel M. De Vos, Reg. No. 37,813; Robert Andrew Diehl, Reg. No. 40,992; Tarek N. Fahmi, Reg. No. 41,402; James Y. Go, Reg. No. 40,621; Richard Leon Gregory, Jr., Reg. No. 42,607; Dinu Gruia, Reg. No. P42,996; David R. Halvorson, Reg. No. 33,395; Thomas A. Hassing, Reg. No. 36,159; Phuong-Quan Hoang, Reg. No. 41,839; Willmore F. Holbrow III, Reg. No. P41,845; George W Hoover II, Reg. No. 32,992; Eric S. Hyman, Reg. No. 30,139; Dag H. Johansen, Reg. No. 36,172; William W. Kidd, Reg. No. 31,772; Michael J. Mallie, Reg. No. 36,591; Andre L. Marais, under 37 C.F.R. § 10.9(b); Paul A. Mendonsa, Reg. No. 42,879; Darren J. Milliken, Reg. 42,004; Thinh V. Nguyen, Reg. No. 42,034; Kimberley G. Nobles, Reg. No. 38,255; Michael A. Proksch, Reg. No. 43,021; Babak Redjaian, Reg. No. 42,096; James H. Salter, Reg. No. 35,668; William W. Schaal, Reg. No. 39,018; James C. Scheller, Reg. No. 31,195; Anand Sethuraman, Reg. No. P43,351; Charles E. Shemwell, Reg. No. 40,171; Maria McCormack Sobrino, Reg. No. 31,639; Stanley W. Sokoloff, Reg. No. 25,128; Allan T. Sponseller, Reg. No. 38,318; Judith A. Szepesi, Reg. No. 39,393; Vincent P. Tassinari, Reg. No. 42,179; Edwin H. Taylor, Reg. No. 25,129; George G. C. Tseng, Reg. No. 41,355; Lester J. Vincent, Reg. No. 31,460; John Patrick Ward, Reg. No. 40,216; Stephen Warhola, Reg. No. 43,237; Charles T. J. Weigell, Reg. No. 43,398; Ben J. Yorks, Reg. No. 33,609; and Norman Zafman, Reg. No. 26,250; my attorneys, and James A. Henry, Reg. No. 41,064; Daniel E. Ovanezian, Reg. No. 41,236; Glenn E. Von Tersch, Reg. No. 41,364; and Chad R. Walsh, Reg. No. 43,235; my patent agents, of BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP, with offices located at 12400 Wilshire Boulevard, 7th Floor, Los Angeles, California 90025, telephone (310) 207-3800, and James R. Thein, Reg. No. 31,710, my patent attorney; with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Title 37, Code of Federal Regulations, Section 1.56
Duty to Disclose Information Material to Patentability

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclosure information exists with respect to each pending claim until the claim is cancelled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is cancelled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclosure all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) Prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) The closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made or record in the application, and

(1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or

(2) It refutes, or is inconsistent with, a position the applicant takes in:

(i) Opposing an argument of unpatentability relied on by the Office, or

(ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application;

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.